UNITED STATES MARINE CORPS
COMMANDING GENERAL
BOX 788100
MARINE CORPS AIR GROUND COMBAT CENTER
TWENTYNINE PALMS, CALIFORNIA 92278-8100

CCO 5104.2
12/01
27 Mar 96

COMBAT CENTER ORDER 5104.2

From: Commanding General
To: Distribution List

Subj: MARINE CORPS AIR GROUND COMBAT CENTER RADIO FREQUENCY ELECTROMAGNETIC FIELD PERSONNEL PROTECTION PROGRAM

Ref: (a) MCO 5100.29
(b) MCO 5104.2
(c) DoDInst 6055.11
(d) MCO 2410.2A
(e) MIL-STD 882B (NOTAL)

Encl: (1) Definitions
(2) Permissible Exposure Limits for Controlled and Uncontrolled Environments, with Application and Measurement Procedures

1. Purpose

a. To establish the Marine Corps Air Ground Combat Center program for the protection of personnel from exposure to electromagnetic fields (EMF) at radio frequencies (RF) from 3 Kilohertz (KHZ) to 300 Gigahertz (GHz), as a component of the Marine Corps Safety Program per reference (a).

b. To implement requirements and RF exposure limits per references (b) and (c), and to supplement reference (d), which established the Marine Corps Electromagnetic Environmental Effects E^3 Control Program.

2. Scope. This Order applies to all personnel potentially exposed to RF exceeding the permissible exposure limits (PEL's) . It applies to peacetime operations and to the maximum extent possible during combat operations and war, to reduce the potential risks associated with RF exposure.

3. Definitions. Enclosure (1) has definitions for technical terms and units used in this Order.

4. Policy. It is the Combat Center policy to:

a. Identify and shield or control by engineering design, protective equipment, administrative actions, or a combination thereof, hazardous RF associated with Marine Corps electronic gear. This policy applies during all phases of equipment design, acquisition, installation, operation and maintenance.

b. Limit personnel to exposure to levels that are below the PEL’s

c. Define and control areas in which RF exposure to personnel could exceed the PEL'S, including simultaneous exposure from more than one RF emitter.

d. Ensure personnel are aware of the potential RF exposures in their workplaces and duties, and the control measures designed to limit their exposures.

e. Investigate and document RF overexposure incidents.

5. Procedures. The Combat Center RF protection program ensures that operations involving personnel exposure to RF levels do not exceed the applicable PEL'S. The program includes:

a. Permissible Exposure Limits

(1) The PEL's for personnel exposure to RF from 3 kHz to 300 GHz are in enclosure (2), Tables 1 and 2, and are consistent with reference (a)

(2) The basic dose limit for RF exposure is a whole body specific absorption rate (SAR) of 0.4 watts per kilogram (w/kg) . This dose is ten times less than the dose at which potentially harmful biological effects in people take place (4 w/kg is the threshold SAR for potential effects)

(3) Listed PEL's are in: root-means-square (rms) electric (E) and magnetic (H) field strengths, plane-wave equivalent power densities and induced body currents associated with exposures to such fields, as a function of frequency, for both controlled and uncontrolled environments.

(a) An area where exposure levels or the induced currents may exceed the values of Table 2, but do not exceed the values of Table 1, is a, "controlled environment." Exposures associated with a controlled environment include:

1 exposures to personnel assigned to duties involving potential RF exposure and who are aware of that potential.

2 exposure of other individuals who enter areas where the potentials for higher levels of RF exist.

3 exposure while moving briefly and occasionally through such areas.

(b) An area where the RF exposure level or the induced current falls below the values given in Table 2 is an "uncontrolled environment." Exposure associated with an uncontrolled environment includes the exposure of individuals who have no knowledge or control over their own exposures. Uncontrolled environmental exposure includes, exposure in living quarters, workplaces or public areas where there are no expectations of finding higher RF levels.

(c) The PEL for controlled and uncontrolled environments in enclosure (2) are different, not based on health risks, but rather as an attempt to maintain lower exposures in areas outside well defined controlled areas.

(d) For partial body exposure, or when SAR or low power device "exclusion rules" apply, relaxed whole body averaged PELs apply. See enclosure (2).

(e) There are no special or additional exposure restrictions or RF exposure limits for pregnant personnel or the unborn child.

b. EMF Exposure Guidance for High Power Microwave (HPM) and Electromagnetic Pulse (EMP) Simulators

(1) HPM Systems. Table 3 of enclosure (2), contains PEL's for a single pulse or series of pulses lasting less than 10 seconds from a HPM narrow-band system in controlled environments. Table 2, has the uncontrolled environment PEL.

(2) EMP Simulator Systems. The PEL for broad band EMP simulators in a controlled environment is in Table 3. Table 2, has the uncontrolled environment PEL.

c. RF Warning Signs

(1) The RF hazard warning sign format contained in ANSI C95.2-1982 will be adhered to. Authorized variations include: subdued signs for camouflage or tactical reasons, or change to improved visibility under certain lighting conditions, provided the general layout of the sign remains the same.

(2) All access points where exposure exceeds the controlled environmental PEL's requires RF warning signs.

(3) Accessible areas where exposures could exceed controlled environmental PEL's by 10 times, require additional warning devices such as: flashing lights, audible signals, barriers, or interlocks, depending on the potential risk of exposure.

d. Protective Clothing. The sole means of protecting personnel should not be routine use of RF protective clothing. Authorized protective equipment necessary for compliance with induced current limits of enclosure (2), include: electrically insulated gloves and shoes for protection against RF shock and burn or for insulation from the ground plane.

e. Investigation of Incidents

(1) All incidents involving actual or possible RF overexposure shall be investigated and documented. The supervisor shall obtain documentation describing the circumstances surrounding the exposure incident, statements from personnel involved in that incident, technical characteristics of the electronic equipment involved and recommendations to prevent similar occurrences. Assistance can be obtained from the Combat Center Radiological Safety Officer in conducting the investigation. The supervisor shall forward a complete report of the incident to the Bureau of Medicine and Surgery, Code 212, Washington, DC 20372 with copy to CMC (SD), HQ USMC, Washington, DC 20380-1775 and an additional copy to the Center Safety Office. In determining the actual amount of RF absorbed by an individual, the Naval Hospital Industrial Hygienist will coordinate and monitor the medical proceedings.

(2) For personnel exposures at, or above, five times the adjusted PEL's of Table 1, the following additional requirements are necessary:

(a) RF measurements for documentation of the suspected RF exposure.

(b) Medical examination and recommendations for medical follow-up.

(c) The Bureau of Medicine and Surgery, Code 212, maintains a repository file of all investigations of exposure incidents in which personnel, within the Marine Corps, were exposed to RF levels more than five times the adjusted PEL'S.

f. RF Safety Training. The supervisor shall ensure that all personnel who are employed in an RF environment receive training before assignment to such work areas. Required refresher training may be incorporated into other periodic safety training programs. Either the supervisor or his authorized representative may conduct the training. Assistance in conducting this training may be obtained from the Center Safety Office. Training requirements include:

(1) The potential hazards of RF.

(2) Identification of all emitters, antennae or radiating surfaces which could possibly expose personnel to high levels of RF energy.

(3) Established procedures and restrictions.

(4) Personal responsibility to limit RF exposures.

(5) Recognition of RF over exposure medical symptoms.

g. Measurement and Evaluation of RF Fields. The Combat Center will evaluate RF hazards using the measurement procedures and techniques recommended in IEEE C95.3-1991, as a basic guidance. This requirement does not preclude using other RF measuring and evaluation methodologies.

(1) Records of surveys, reports, calculations, and control measures imposed shall be maintained for each fielded RF emitter which is capable of exceeding the PEL' 5

(2) Where collated in fixed arrangements, such as communication sites, multiple emitters' RF evaluation data should include a determination of the weighted contribution from expected simultaneously operated emitters to ensure that the effective RF exposure levels are below the PEL.

6. Actions

a. Unit Commanding Officers shall:

(1) Ensure delineation and posting of RF controlled environments as defined in this Order with the RF hazard warning signs.

(2) Ensure no exposures of personnel to RF levels more than the applicable PEL's of Table 1 during operational use, training or maintenance of RF emitting equipment.

(3) Ensure investigation and documentation of personnel exposure incidents involving alleged or actual overexposures to RF, as detailed in above.

(4) Notify CMC (SD) whenever issues may arise in local civilian communities regarding exposure of individuals to RF from Marine Corps operations.

J. D. MAJCHRZAK
Chief of Staff

DISTRIBUTION: A-1

DEFINITIONS

1. Average Time (T_{avg}). The time period over which exposure is averaged for determining compliance with a PEL value.

2. Controlled Environment. Locations where RF exposures may exceed the levels given in table 2, but do not exceed the levels in table 1, of enclosure (2). Generally, controlled environments represent areas that may be occupied by personnel who accept potential exposure as a part of their duties, by individuals who knowingly enter areas where such levels are to be expected, and by personnel passing through such areas. Existing physical arrangements or areas, such as fences, perimeters, or weather deck(s) of a ship may be used to establish controlled environments.

3. Electric Field. A fundamental component of electromagnetic (EM) waves, which exists when there is a voltage difference between two points in space.

4. Electric Field strength (E) . The magnitude of the electric field expressed in volts per meter (V/rn)

5. Exposure, Partial Body. Partial body exposure is the result of EMF affecting different masses within the body in unlike amounts. Fields that are nonuniform over masses comparable to the human body occur due to highly directional sources, reradiating sources, standing waves, or when in the antenna's near-field region.

6. Far Field Region The region far enough from an antenna that the power per unit area decreases with the square of the range. In the far-field region, the field has a predominately planewave character; i.e., uniform distributions of electric and magnetic fields in planes transverse to the direction of propagation.

7. Fluence. The energy density of the EMF when integrated over the duration of the exposure, usually expressed in units of joules per square centimeter (J/cm^2)

8. Hertz (Hz). The unit of expressing frequency. One hertz equals one cycle per second. Commonly used multiples are kilo (1000) hertz (kHz), mega (1,000,000) hertz (MHz), and giga (1,000,000,000) hertz (GHz)

9. Human Resonance Range The frequency region where absorption of RF energy in the body is enhanced. For sizes ranging from a baby to an adult, peak absorption varies depending on the individuals size relative to the wavelength and orientation relative to the polarization of the wave. The PEL's have been established to cover the range in human sizes, shapes and positions.

10. Magnetic Field. A fundamental component of EM waves produced by a moving electric charge.

11. Magnetic Field Strength (H) . The strength of the magnetic field expressed in amps per meter (A/rn)

12. Mathematical Expressions. Standard notations are used in the text and the tables to show operations, such as, a/b to mean b divides a, ab or a(b) or (a) (b) to mean a multiplies b, ab to beam a raised to the b power, and the symbol < to mean less than.

13. Near Field Region. A region generally in close proximity to an antenna or other radiating structure in which the electric and magnetic fields do not exhibit a plane-wave relationship, and the power does not decrease with the square of distance from the source but varies considerably from point to point. The near field region

is further subdivided into the reactive near field, which is closest to the radiating structure and contains most or nearly all of the stored energy, and the radiating near field, where the radiating field predominates over the reactive field but lacks substantial plane wave character and is complicated in structure. For most antennas, the outer boundary of the reactive near field region is considered to occur at a distance of one half wavelength from the antenna surface.

14. Permissible Exposure Limit (PEL) . The PEL is established for the protection of personnel. There are no expectations that any adverse health effects will occur with exposures that are within the PEL, even under repeated or long-term exposure conditions. In controlled environments, where restrictions on access may be implied, the PEL is based on maintaining exposures below a SAR of 0.4 W/kg.. A SAR of 0.4 W/kg is 10 times below the level (4 W/kg) considered a threshold, above which there is an increasing probability of adverse biological effects, and below which there is no evidence of any harm to health. Public areas, where access is not restricted, maintain lower levels (equivalent to a SAR of 0.08 W/kg) . Since SAR is not an easily measured quantity, PEL's are given in terms of measurable field parameters E, H, or S as a means of demonstrating compliance with SAR.

15. Plane Wave. An EM wave characterized by mutually orthogonal electric and magnetic fields that are related by the impedance of free space (377 ohms) . For plane waves, S, E, and H exhibit the following relationship: $S\text{-}E^2/3770 = 37.7\ H^2$ where S is in units of mW/cm^2, E is in V/rn and H is in A/rn.

16. Power Density (S). Radiated power per unit area, expressed in units of watts per square meter (W/m^2) or milliwatts or microwatts per square centimeter (mW/cm^2 or uW/am^2). The term, plane wave equivalent power density, refers to the magnitude of S that would exist for an EM wave in free space having the same E or H fields.

17. Radio Frequency (RF) . The RF region is defined as extending from 3 kHz to 300 GHz.

18. Reradiated Field. EMF resulting from currents induced in a secondary, predominantly conducting object, by EM waves incident on that object from one or more primary radiating structures or antennas. Reradiated fields are sometimes called reflected or scattered fields. The scattering object is sometimes called a reradiator, or a secondary or parasitic radiator

19. RF Hot Shot. A highly localized area of relatively intense RF that manifests itself as.

a. Intense electric or magnetic fields immediately adjacent to conductive objects immersed in lower intensity ambient fields, or

b. Localized areas where there exists a concentration of RF fields caused by reflections or narrow beams produced by high gain radiating antennas or other highly directional sources.

c. For both descriptions, the fields are characterized by very rapid changes in field strength. RF hot spots are normally associated with very nonuniform exposure of the body (partial body exposure). The term RF hot spots should not be confused with an actual thermal hot spot in an absorbing body.

20. Root Mean Square (rms). The effective $value_1$ or the heating value, of a periodic EM wave. The rms value for E or H fields is obtained by taking the square root of the mean of the squared values for E or H over an area equivalent to the vertical cross section of the human body (projected area).

21. Specific Absorption Rate (SAR). The time rate at which RF energy is imparted to an element of biological body mass. Average SAR in a body is the time rate of the total energy absorbed divided by the total mass of the body. SAR is expressed in units of watts per kilogram (W/kg) . Specific absorption (SA) refers to the amount of energy absorbed over an exposure time period and is expressed in units of joules per kilogram (J/kg).

22. Uncontrolled Environments. Locations where RF exposures do not exceed the PEL's in table 2 of enclosure (3). Such locations generally represent living quarters, workplaces, or public access areas where personnel would not expect to encounter higher levels of RF energy.

PERMISSIBLE EXPOSURE LIMITS FOR CONTROLLED AND UNCONTROLLED ENVIRONMENTS, APPLICATION AND MEASUREMENT PROCEDURES

Table 1. Permissible Exposure Limits for Controlled Environments

1. Radiofrequency Electromagnetic Field

Frequency Range (f) in MHz	Electric Field (E) in v/rn	Magnetic Field (H) in A/rn	Power Density (S)in *m*W/cm^2 E then H	Averaging Time (T_{avg})E,H,5
0.003-0.1	614	163	(10^2,10^6)	6
0.1-3.0	614	16.3/f	102^2, l0^4/f^2)	6
3-30	1842/f	16.3/f	(9oo/f^2, 10^4/f2)	6
30-100	61.4	16.3/f	(1.0, i0^4 /f^{2}6	
100-300	61.4	0.16	1	6
300-3000			f/300	6
3000-15000			10	6
15000-300000			10	6l6000/f$^{1.2}$

2. RF Induced Current Restrictions

Frequency Range (f) MHz	Maximum Current Through Both Feet (mA)	Maximum Current Through Each Foot (mA)	Contact Current (mA)
0.003-0.1	2000f	lOOOf	lOOOf
0.1-100	200	100	100

3. Pulsed RF Fields

Frequency Range (f) MHz	Peak Electric Field (E) kV/m	Peak Power Density/Pulse For Pulse Duration <l00 msec (mW/cm^2)
0.1-300000	100	l00(PEL) (T_{avg})/(5) (pulse width)

4. Partial-Body Exposure

Frequency Range (f)MHz	Peak Value of Mean Squared Field (V^2/m^2 or A^2/m^2)	Equivalent Power Density (mW/cm^2)
0. 1-300	<20E^2 or 20H^2	
300-6000		<20
6000-96000		<20(f/6000)$^{0.25}$
96000-300000		40

Table 2. Permissible Exposure Limits for Uncontrolled Environments

1. Radiofreguency Electromagnetic Fields

Frequency Range (f) in MHz	Electric Field (E) in V/m)	Magnetic Field (H) in A/m)	Power Density (S)in mW/cm^2 E then H	Averaging Time (T_{avg})(E,S)(H)	
0.003-0.1	614	163	(10^2,10^6)	6	6
0.1-1.34	614	16.3/f	(10^2, 10^4/f^2)	6	6
1.34-3.0	823.8/f	16.3/f	(180/f^2,10^4/f^2)	f^2/.3	6
3-30	823.8/f	16.3/f	(180/f^2,10^4/f^2)	30	6
30-100	27.5	158.3/f$^{1.668}$	(0.2, 9.4x10^5/f$^{3.336}$)	30	.0636/f$^{1.337}$

ENCLOSURE (2)

100-300	27.5	0.0729	0.2	30	30
300-3000			f/1500	30	
3000-15000			f/1500		9000/f
15000-300000			10		$616000/f^{1.2}$

2. RF Induced Current Restrictions

Frequency Range (f)in MHz	Maximum Current Through Both Feet(mA)	Maximum Current Through Each Foot (mA)	Contact Current (mA)
0.003-0.1	900f	450f	450f
.1-100	90	45	45

3. Pulsed RF Fields

Frequency Range (f)MHz	Peak Electric Field (E)kV/m	Peak Power Density/Pulse for Pulse Duration<l00msec (mW/cm^2)
0.1-300000	100	$(PEL)(T_{avg})/(5)(Pulse\ Width)$

4. Partial Body Exposures

Frequency Range (f)MHz	Peak Value of Mean Squared Field (V^2/m^2 or A^2/m^2)	Equivalent Power Density (mW/cm^2)
0.1-300	$<20E^2$ or $20H^2$	
300-6000		4
6000-30000		f/1500
30000-300000		20

Table 3. Permissible Exposure Limits for High Power Microwave Devices and Electromagnetic-Pulse Devices

1. High Power Microwave (Narrow-Band) Systems

Frequency Range (f) in MHz	Peak Electric Field (E) in kV/m	Maximum Fluence Level in Controlled Environments for any Single Pulse or Series of Multiple Pulses Lasting <10sec within any 6 min period in J/cm^2
100-300	200	0.36
300-3000	200	3.6 (f/3000)
>3000	200	3.6

2. Electromagnetic-Pulse (Broad-Band) Systems

Frequency Range(f)in MHZ	Peak Electric Field(E)in Controlled Environments(kV/m)
0.1-300000	100

Application and Measurement Notes

a. The Institute of Electrical and Electronic Engineers (IEEE), provides guidance on measuring procedures and techniques for RF hazard evaluations in the following standards:

(1) IEEE C95.1-1991. Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 30.0 GHz.

(2) IEEE C95.3-1991. Recommended Practice for the Measurement of Potentially Hazardous Electromagnetic Fields - RF and Microwave.

(3) The guidance in these standards or that below, is not intended to preclude use of other appropriate RF hazard measuring and evaluation methodologies.

b. Tables 1 and 2

(1) The PEL's refer to time averaged exposure values obtained by spatial averaging of S or the mean squared H and H values over an area equivalent to the vertical cross section of the human body (projected area). In nonuniform fields, spatial peak values may exceed the PEL's even though the spatially averaged value does not exceed the PEL'S. Spatial peak values are limited by the partial body PEL's given in sections a. of Tables 1 and 2.

(2) For exposures at frequencies less than 300 MHz, the applicable PEL is given in terms of rms E or H values. Although not technically correct under near field conditions, PEL's also may be expressed in terms of plane wave equivalent values as shown by the S values in parentheses for the E and H fields, respectively, at frequencies less than 100 MHz.

(3) PEL's in section 1. of Table 1 refer to values averaged over any six minute period for frequencies less than 15 GHz, and over shorter periods for high frequencies (10 seconds at 300 GHz) . The PEL's in section 1. of Table 2 refer to values generally averaged over any six or thirty minute period for frequencies less than 3 GHz. For certain frequency intervals, the averaging period will vary as a function of frequency as shown in sections of Tables 1 and 2.

(4) For exposure duration less than the averaging period, the maximum permissible exposure level, PEL', in any time interval equal to the averaging period is, PEL' = PEL (Tavg/Texp), where Texp is the exposure duration in that interval expressed in the same time units as Tavq.

(5) Measurements to determine adherence to the PEL should be made at distances of at least 20 centimeters (am) or greater from any reradiating objects of reflective surfaces.

(6) The PEL values may be relaxed in the case of partial body exposure, or by reference to the SAR exclusion rules, or the low power device exclusion rules, as follows:

(a) Partial Body Exposure. Relaxation of the PEL's of sections 1. of Tables 1 and 2 are allowed for exposures limited to a portion of the body, when exposure is from highly directional sources or from substantially nonuniform fields over an area equivalent to the body. Maximum values for partial body exposure limits are in sections 4. of Tables 1 and 2. Partial body limits do not apply in the case of direct exposure to the eyes.

(b) SAR Exclusion Rule The PEL's in sections a. of Tables 1 and 2 may relaxed by reference to SAR limits through calculations or measurements as follows:

1 Controlled Environment Exclusion

a At frequencies between 3 kHz and 100 kHz, the PEL can be exceeded, if it can be shown that the peak rms current density, as averaged over any 1 CM area of tissue and over one second, does not exceed $0.035(f) mA/cm^2$ where f is in kHz.

b At frequencies between 100 kHz and 6 GHz, the PEL may be exceeded if the exposure conditions can be shown to produce SAR's below 0.4 W/kg as averaged over the whole body, and spatial peak SAR values not exceeding 8 W/kg as averaged over any one gram of tissue; except for the hands, wrist, feet and ankles where the spatial peak SAR shall not exceed 20 W/kg as averaged over any 10 grams of tissue, and the inducted body currents conform with the values in section 2. of Table 1.

c At frequencies above 6 GHz, where body absorption is quasi-optical and body resonance considerations do not apply, the PEL's may be relaxed using the time-average limits for partial body exposures given in section 4. of table 1.

2 Uncontrolled Environment Exclusion

a At frequencies between 3 kHz and 100 kHz, the PEL can be exceeded, if it can be shown that the peak rms current density, as averaged over any 1 am^2 area of tissue and over one second, does not exceed $0.0157(f)rnA/am^2$ where f is in kHz.

b At frequencies between 100 kHz and 6 GHZ, the PEL may be exceeded if the exposure conditions can be shown to produce SAR's below 0.08 W/kg as averaged over the whole body, and spatial peak SAR values not exceeding 1.6 W/kg as averaged over any one gram of tissue; except for the hands, wrist, feet and ankles where the spatial peak SAR shall not exceed 4 W/kg as averaged over any 10 grams of tissue, and the inducted body currents conform with the values in section 2. of Table 2.

c At frequencies above 6 GHz_1 where body absorption is quasi-optical and body resonance considerations do not apply, the PEL's may be relaxed using the time-average limits for partial body exposures given in section 4. of Table 2.

(a) Low Power Device Exclusion. At frequencies between 100 kHz and 1.5 GHz, the PEL's of Tables 1 and 2 may be exceeded under the following conditions for devices in which the radiating structure is not maintained within 2.5 cm of the body:

1 Controlled environment low power device exclusion pertains to devices that emit RF energy under the control of an aware user. That exclusion addresses exposure of the user.

a At frequencies between 100 kHz and 450 MHz, the PEL may be exceeded if the radiated power is 7 watts, or less.

b At frequencies between 450 and 1500 MHz, the PEL may be exceeded if the radiated power is (7) (450/f) watts, or less, where f is in MHz.

2 Uncontrolled environment low power device exclusion pertains to devices that emit RF energy without control or knowledge of the user.

a At frequencies between 100 kHz and 450 MHz, the PEL may be exceeded if the radiated power is 1.4 watts, or less.

b At frequencies between 450 and 1500 MHz, the PEL may be exceeded if the radiated power is (1.4) (450/f) watts or less, where f is in MHz.

(7) In applying the PEL's listed in Tables 1 and 2 for different situations, such as characterizations of the EMF'S, determining the PEL safe distances or assessment of personnel exposures, different measurement considerations may be applied as follows:

(a) RF Field Characterization. For reactive near field conditions, generally both the E and H fields must be determined for frequencies less than 300 MHz. For frequencies equal to or less than 30 MHz, that can only be accomplished by measurement of both field strengths. The need to measure both E and H fields below 300 MHz derives from a consideration of the spatial variation in E and H field strengths in the reactive near field of any antenna. PEL boundary locations are to be established by determining the farthest distance from the radiating source that a PEL value can be exceeded using appropriate measurement techniques for the conditions of measurements.

(b) Assessment of Personnel Exposure. In determining whether a person has received exposure in excess of the PEL, exposure averaging times and whole body spatial averaging are important factors in making the assessment. In other cases, determination of the vertical E field component rather than the total E field is appropriate in determining whether an individual received a high exposure in terms of whole body averaged SAR'S. For low power devices, such as hand held, mobile and marine transmitters, the low power exclusion criteria can be used in assessing exposure conditions. Even though those low power devices may have localized fields that exceed the PEL field values, the actual whole body or spatial peak SAR's will not be exceeded.

(8) For mixed or broad band fields at a number of frequencies for which there are different values of the PEL, the fraction of the PEL in terms of E^2, H^2, or S incurred within each frequency interval should be determined and the sum of all such fractions should not exceed unity. A detailed example for that type of calculation is in Appendix C of IEEE C95.1-1991.

c. Section 2., Tables 1 and 2

(1) Guidance is provided for limiting the RF induced currents (averaged over any ONE second) in the human body for free standing conditions (no skin contact with metallic objects); and under conditions of grasping contact with metallic bodies to limit the maximum RF current through an impedance equivalent to that of the human body

(2) Adherence to the controlled environment induced body current limits will prevent localized SAR in the ankles or wrists from exceeding 20 W/kg. For uncontrolled environments, where individuals would not be aware of the existence of RF currents, the values are set at levels that will not be normally perceptible to individuals. In general, between 3 kHz and 100 kHz, the perception threshold is related to a tingling or prickling sensation; while between 100 kHz and 100 MHz, the perception threshold is related to a sensation of heat or warmth. Under some conditions, touching conductive objects that are in the vicinity of a radiating RF antenna could result in a flow of RF current of sufficient magnitude to be painful or that may produce a burn at the point of contact.

(3) Evaluation of induced RF currents will generally require a measurement to determine the RF current flowing to ground through the feet of the individual, or the RF current flowing through the hand in contact with a conductive surface. Currents may also be measured by use of instrumentation which can simulate the electrical characteristics of the human body at the frequency of the current to assess the expected current that would flow if a person were to come into contact with a conductive object.

(4) Under various exposure conditions, application of the field strength limits in section a. of tables 1. and 2., in conjunction with the induced current limits in section b., may not be measurable. Many variables, such as, near field exposure conditions, physical contact with or close proximity to nearby conductive surfaces, RF absorption enhancement under resonance frequency-conditions, inherent differences in human body sizes, will affect the measured induced currents.

(a) While section a. specifies maximum time-averaged exposure field strengths, it is recommended that in those cases where RF shock and burn conditions exist, action be taken to prevent occurrence, either by reducing the induced currents or by restricting area access.

(b) In controlled environments, measures can be taken to reduce the probability of hazardous conditions. Such measures may include: protective gloves, awareness programs so that individuals are alerted to the possible presence of induced currents between the human body and conductive objects, and work practices which lessen the probability of receiving unexpected shocks or burns.

(c) Short or momentary exposure in which induced body currents exceed the levels of section b., such as may occur while moving through or in an area near an antenna, can be permitted when conditions are not likely to cause an individual to encounter RF shock or burns from inadvertent contact with conductive surfaces.

d. Section a., Tables 1. and 2

(1) Peak power exposure limitations are provided for pulsed conditions where each pulse is less than 100 milliseconds (msea) and there are no more than five pulses in the time averaging period. Those limits are given to prevent unintentionally high exposure and to preclude high SA for decreasingly short widths of pulses. If there are more than five pulses during any time period equal to the averaging time, or if the pulse duration is greater than 100 msea, the time averaged S should not exceed the PELs given in section a. of tables 1. and 2.

(2) For exposure to RF pulses in the frequency range of 0.1 to 300,000 MHz, exposure is limited by either a peak (temporal) E field of 100 kV/m for each pulse or in terms of a peak S value for each single pulse, whichever is more limiting. A maximum exposure to five such pulses, with a pulse repetition rate of at least 100 msea, is permitted during any period equal to the averaging time. For low frequencies and short pulses, 100 kV/m will be the more conservative limit. For high frequencies and longer pulses, peak S will be more conservative.

(3) The limitation on RF fields under pulsed conditions, (less than 100 msec), means that the PEL as averaged over any 100 msec is reduced by a factor of five, and a maximum of five such pulses are permitted during any period equal to the averaging time. For example, in the microwave region for exposure to a single pulse, the SA over any six minute period is limited to 28.8 J/kg per pulse (spatial average) with a maximum of five such pulses (i.e., (5) (28.8 J/kg) = 144 J/kg), which is equivalent to a SAR of 0.4 W/kg over a six minute period).

e. Section d. Tables 1. and 2

(1) Implicit in the PEL definition of a whole body averaged SAR of 0.4 W/kg for a controlled environment and 0.08 W/kg for an uncontrolled environment, is the assumption that spatial peak SARs may occur that exceed the whole body averaged values by a factor of more than 20 times. The values provided in section d. of tables 1. and 2. allow for equating substantially nonuniform field exposure or partial body exposure to an equivalent uniform field exposure.

(2) For exposure of parts of the body, the spatially averaged PELs given in section a. may be relaxed provided the peak value of the mean square field strength does not exceed 20 times the square of the allowed spatially averaged values at frequencies below 300 MHz, or the equivalent S levels do not exceed the levels shown in section d. as averaged over the Tavg periods given for frequencies above 300 MHz.

(3) The rules above for relaxation of the limits for partial body exposure do not apply for direct exposure of the eyes, but the SAR exclusion rules can still be used to show conformance to the PEL despite localized S values above the specified whole body average. In such cases, exposures to the eyes are limited by the basic exposure criteria of a whole-body averaged SAR of 0.4 W/kg (controlled environment) or 0.08 W/kg (uncontrolled environment), and spatial peak SARs of 8 W/kg (controlled environment) or 1.6 W/kg (uncontrolled environment) as averaged over any one gram of tissue.

f. Table 3

(1) The exposure guidance given is based on HPM narrow-band systems operating within the following parameters: maximum pulse width of 10 microseconds, peak S of 0.1 to 10 kW/am^2, frequency greater than 100 MHz, repetition rate not greater than 10 pulses per second.

(2) The exposure guidance is specific for HPM narrow-band systems and does not apply to exposure from EMP broad band simulator systems. If the HPM system is not within those parameters, then PELs in table 1. apply.

(3) For personnel exposure to HPM in a controlled environment, the measured fluence is not to exceed the values given in section a. of table 3., for any single pulse or series of multiple pulses lasting less than 10 seconds. The total fluence delivered over any six minute period shall not exceed the values in section a. of table 3. In all cases, the instantaneous H field shall not exceed 200 kV/m.

(4) If the exposure values given in section a. of table 3. cannot be met, then the total measure SA to the head shall not exceed 150 J/kg for any single pulse or 150 J/kg for multiple pulses in any six minute period.

g. Table 4. Measurements of EMF from broad-band EMP simulator systems require special instrumentation and techniques because of the inherent rapid rise time and the high field strengths associated with EMP. Refer to the technical office of the DoD Components for measurement and evaluation assistance.